Water-Level Changes at Devil's Hole Associated with Barometric Pressure, Earth Tides and Earthquakes

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Collaborators

- Keith Halford, USGS, Nevada District

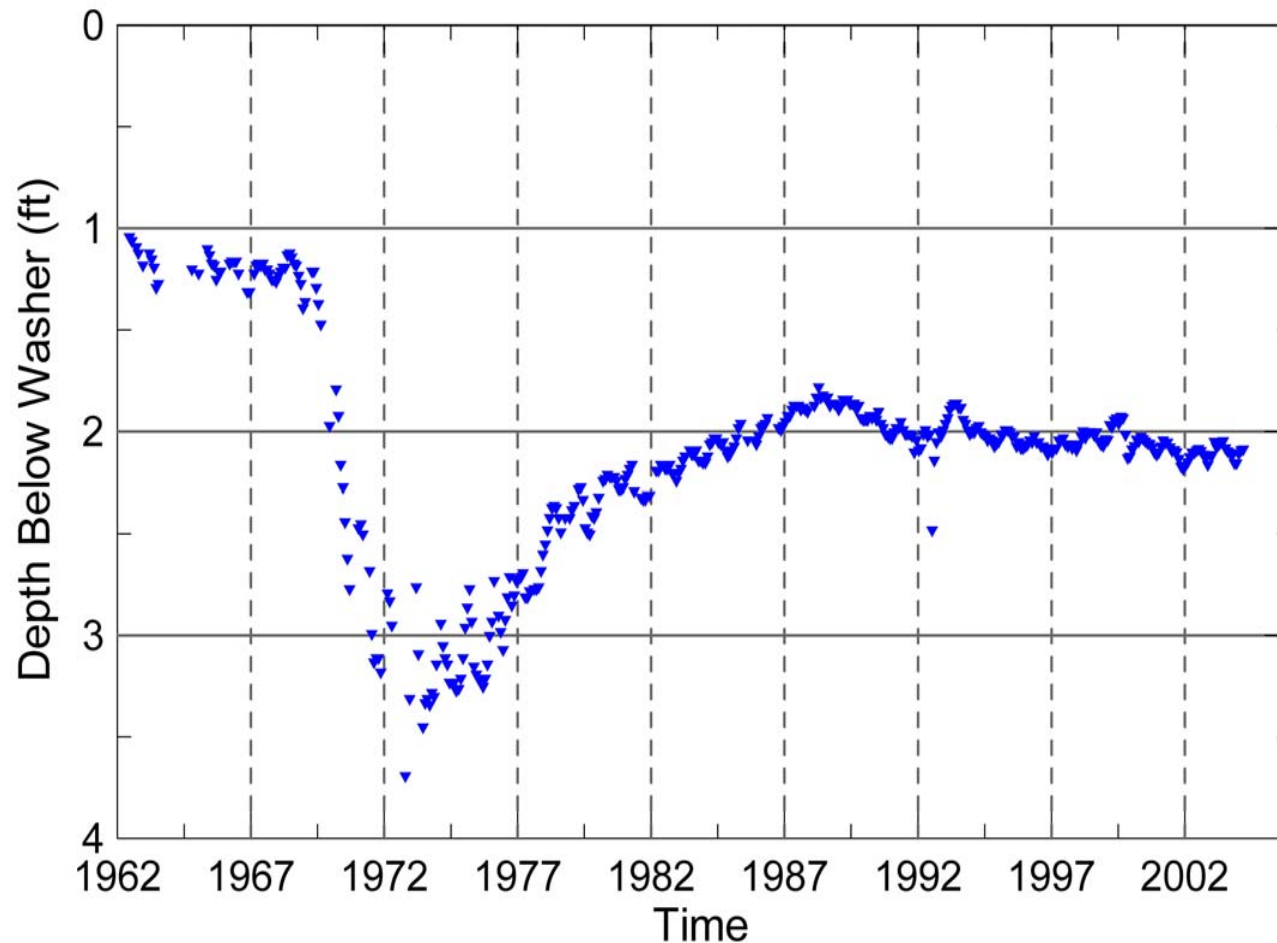- Randy Laczniak, USGS, Nevada District

Outline

- Effects of atmospheric pressure and earth tides on water levels

- Filtered Devil's Hole water-level record

- Effects of earthquakes on water levels

Monthly Mean Water Level (Jun-62 to Mar-04)

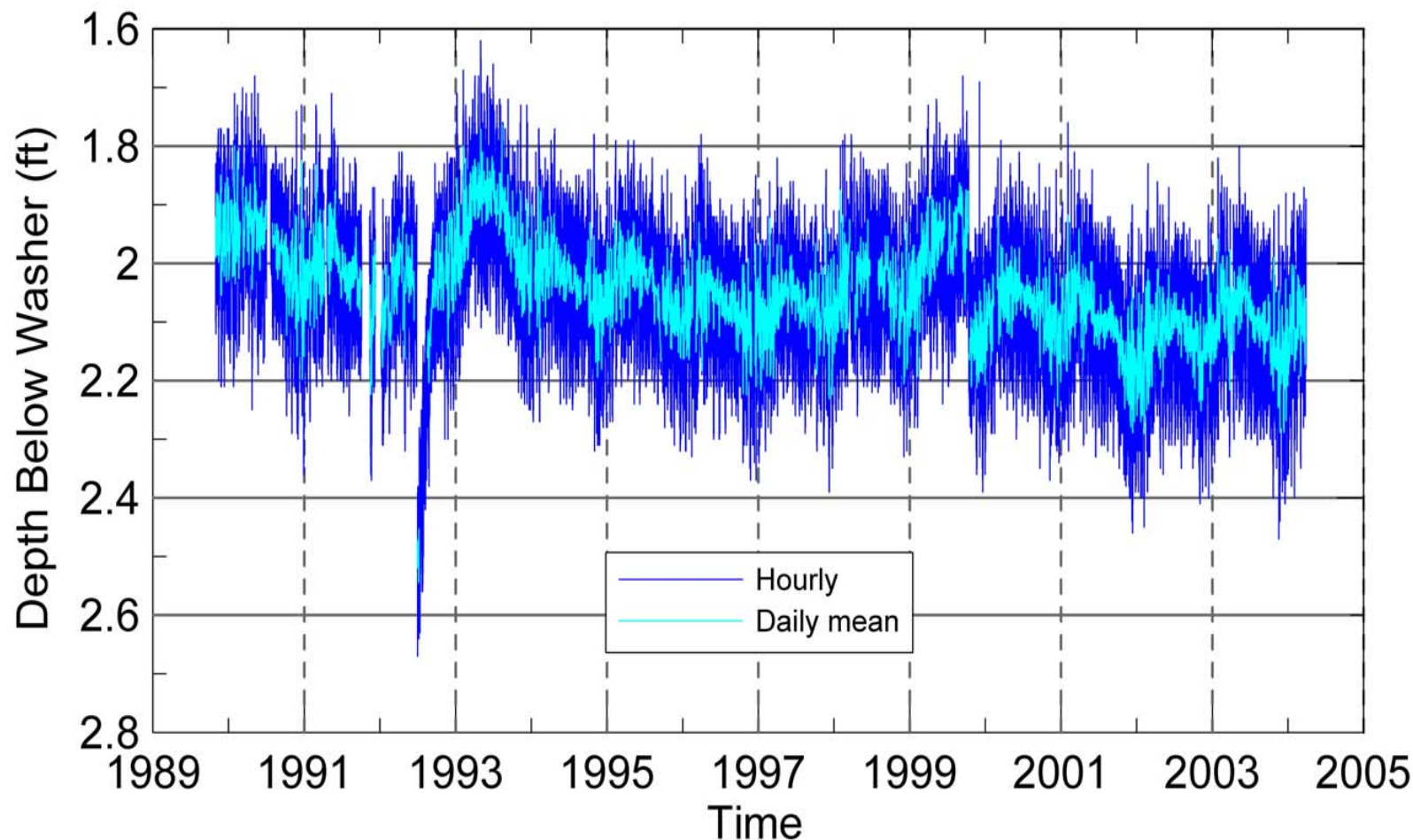# National Park Service

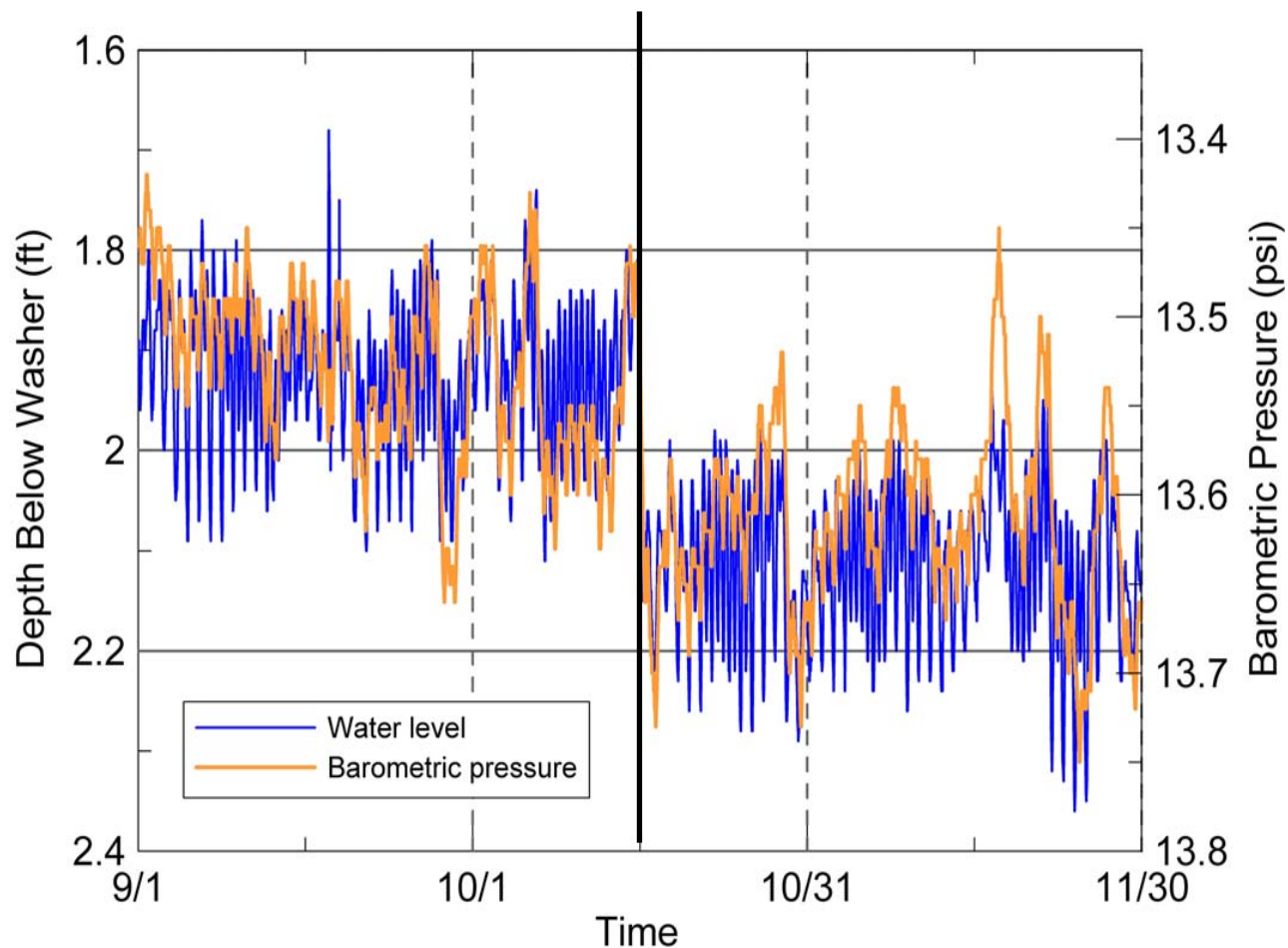Hourly & Daily Mean Water Level (Oct-89 to Mar-04)

Factors Influencing Water Level

- Atmospheric pressure changes
- Earth tides
- Crustal strain (e.g., earthquakes)
- Ground-water development
- Climate change

# Barometric Pressure & Water Level during the 1999 Hector Mine Earthquake

Methods

- **Data requirements**
  - Hourly BP and WL time series
  - Theoretical Earth tide time series (Harrison, 1971)
- **Analyze how water level is affected by earth tides and changes in barometric pressure**
  - Used Visual Basic fitting program (developed by K. Halford, USGS) that estimates a **multiplier** that changes the amplitude and a **constant** that shifts the phase of each time series response
  - Used small data sets (15-30 day time periods)
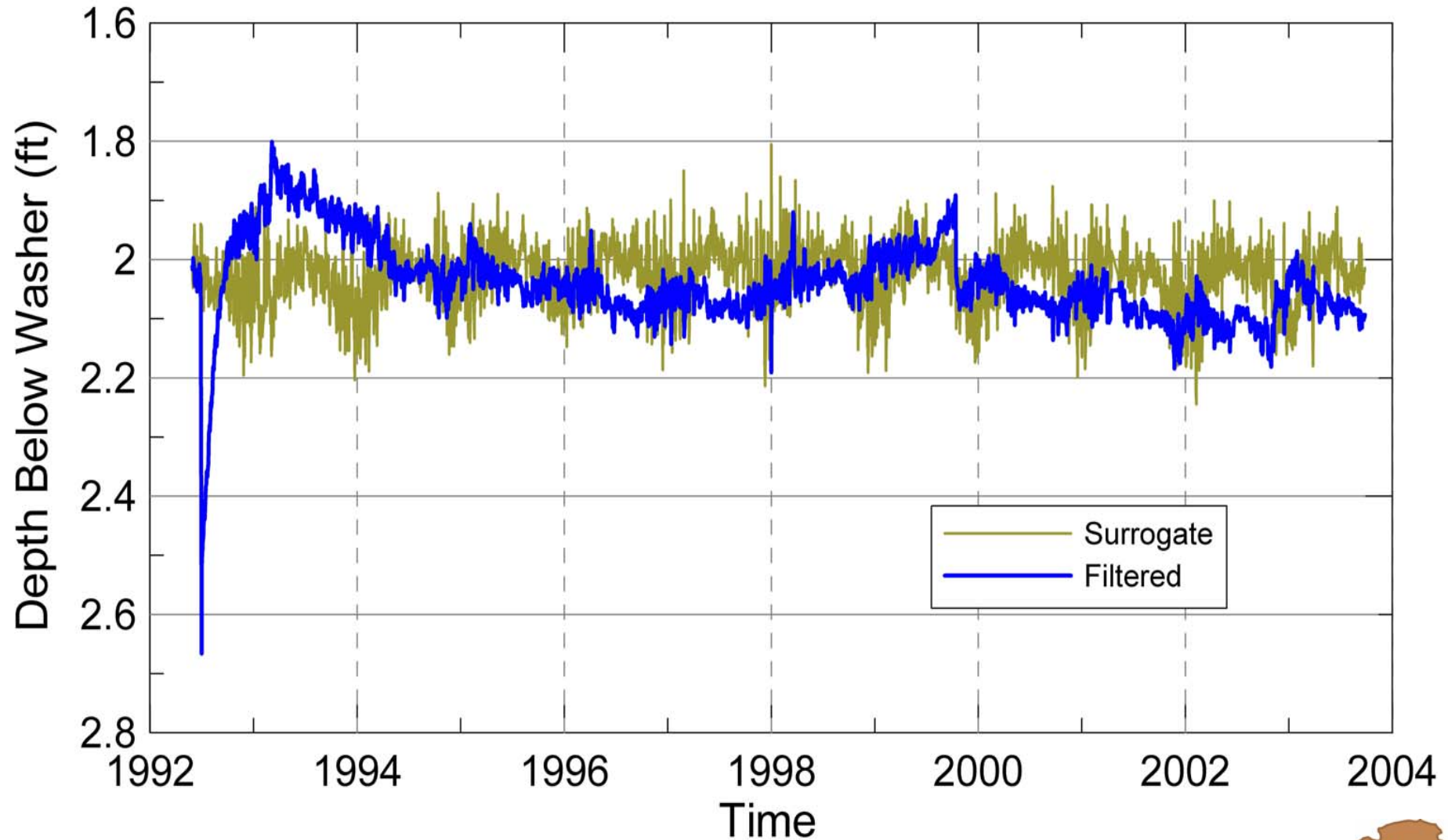 - Check for consistency over time

Methods

- **Filter entire data set**
  - Used average multiplier and constant
  - Developed a Fortran program to process over 10 years of hourly data
  - Generated water-level record filtered for the effects of barometric pressure and earth tides

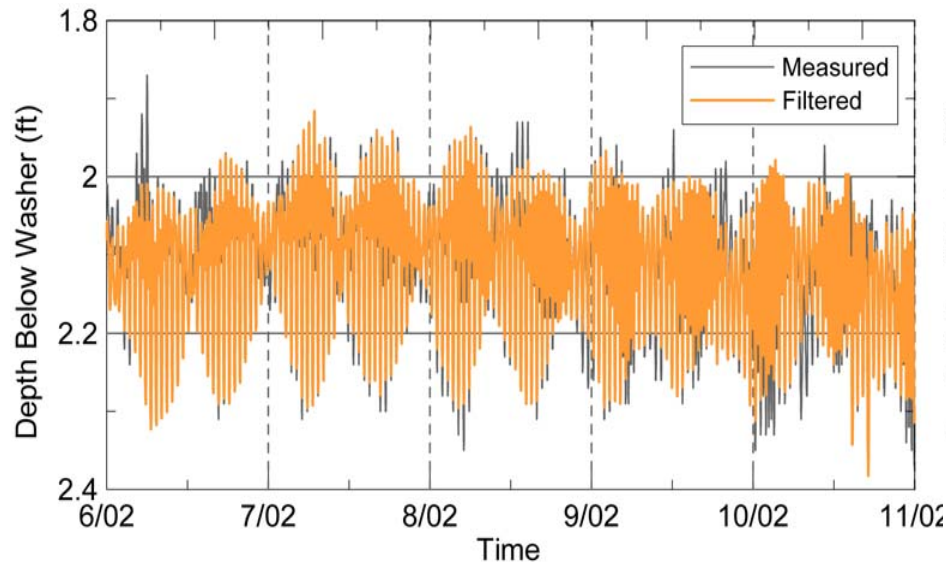# Measured & Filtered Daily Mean Water Level
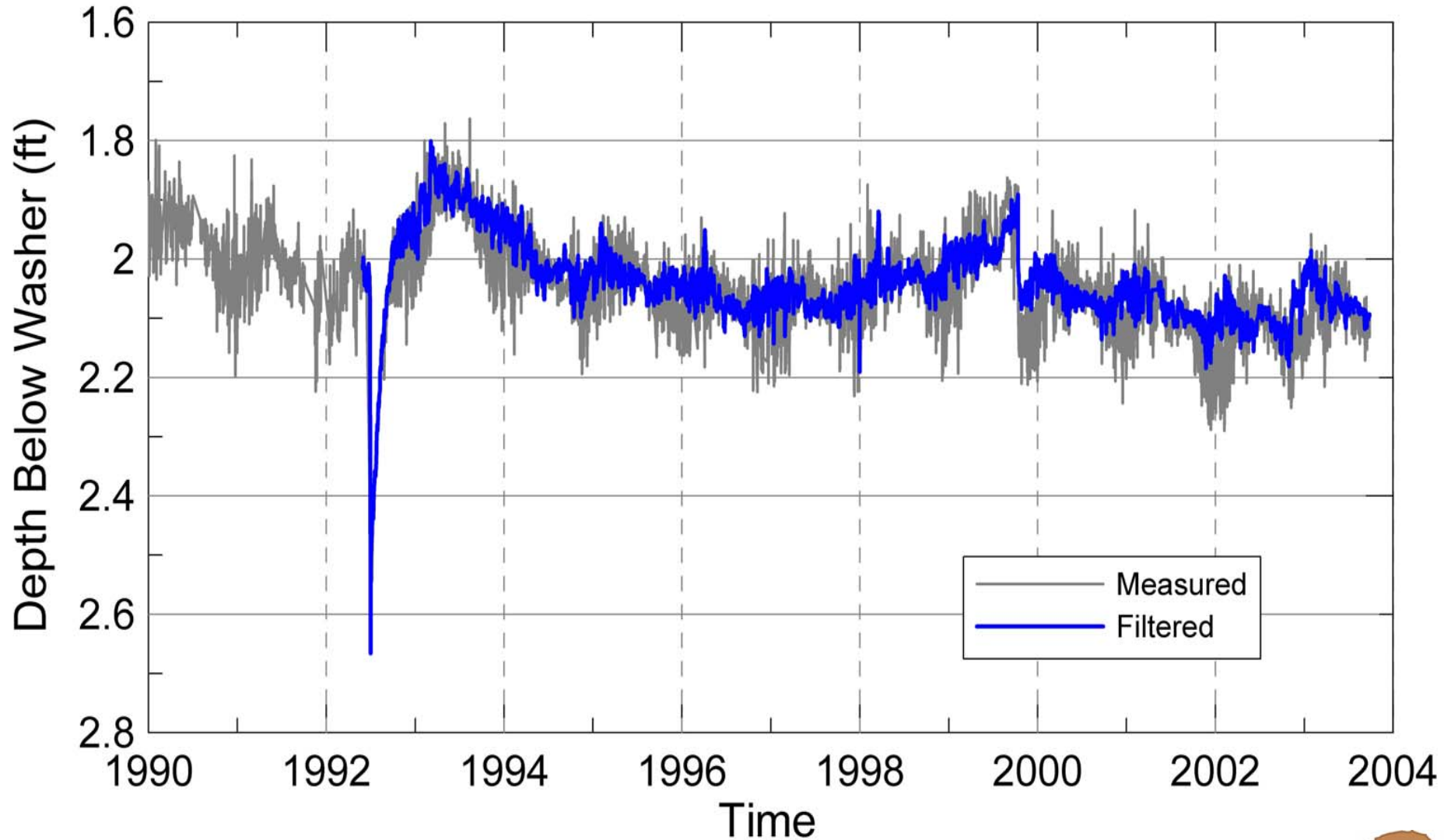
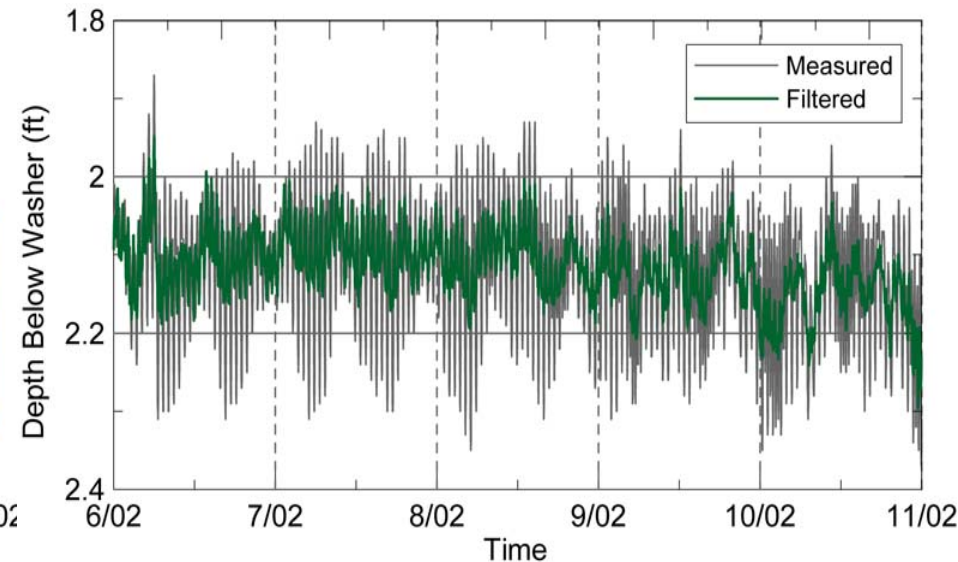# Surrogate & Filtered Daily Mean Water Level

Earth Tide Sensitivity

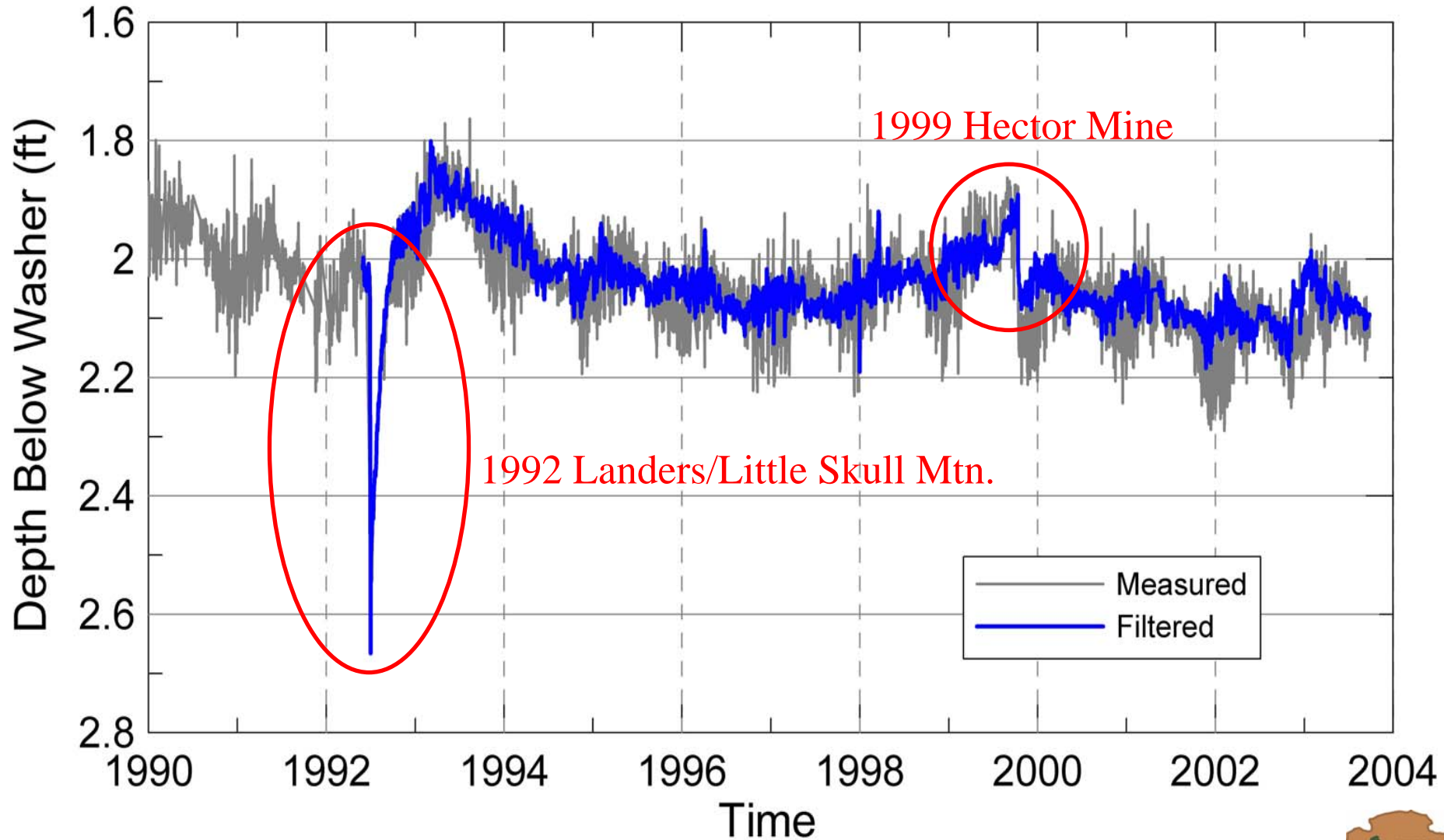## 6-month period – hourly water level

Filtered for barometric pressure only

Filtered for Earth tides only

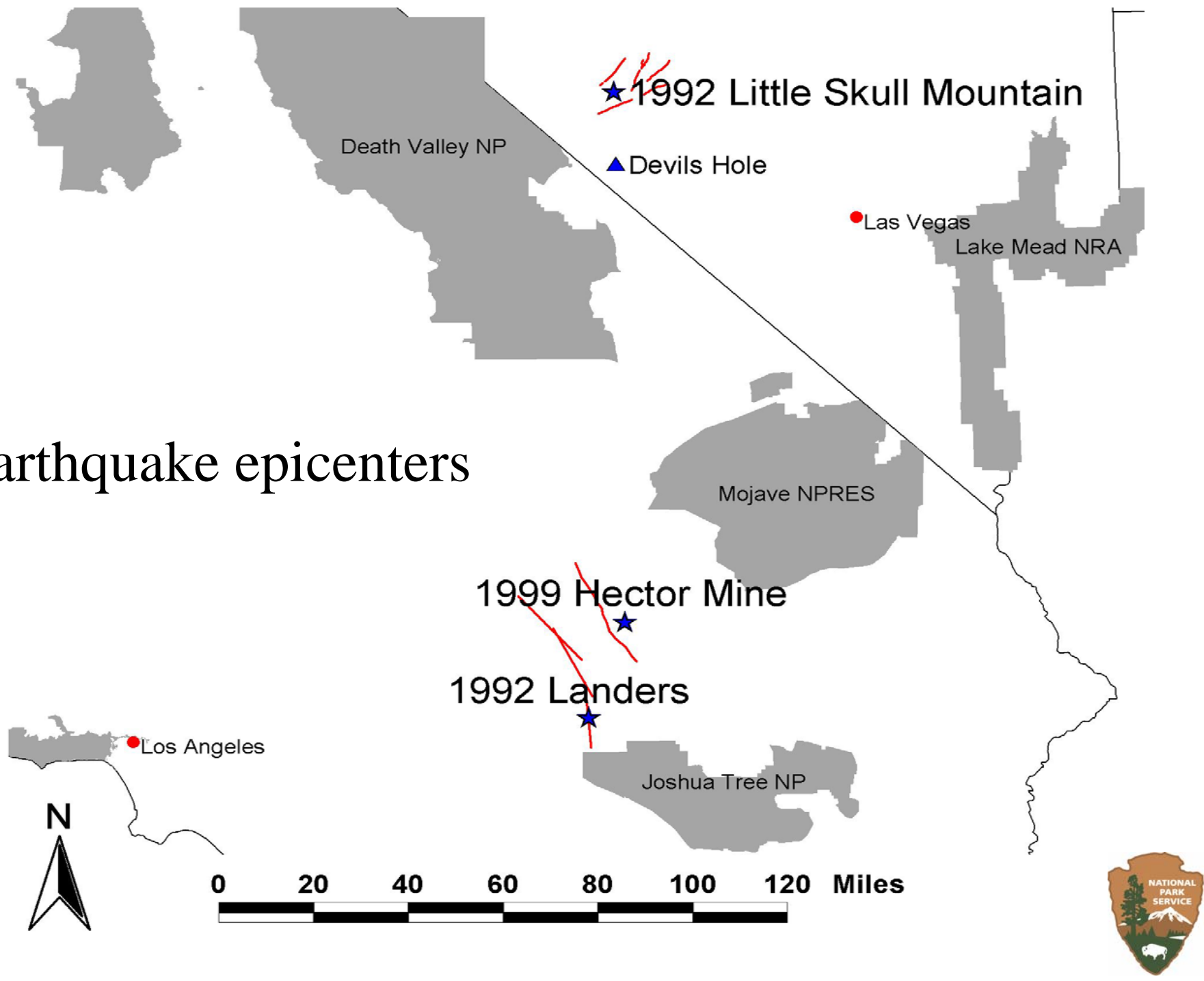# Measured & Filtered Daily Water Level

Summary & Conclusions

- Water-level fluctuations due to air pressure and earth tides do not exceed 0.4 ft at Devil's Hole

- Installation of a barometer

- Filtered water level data helps to isolate other factors that influence water levels (e.g., earthquakes)
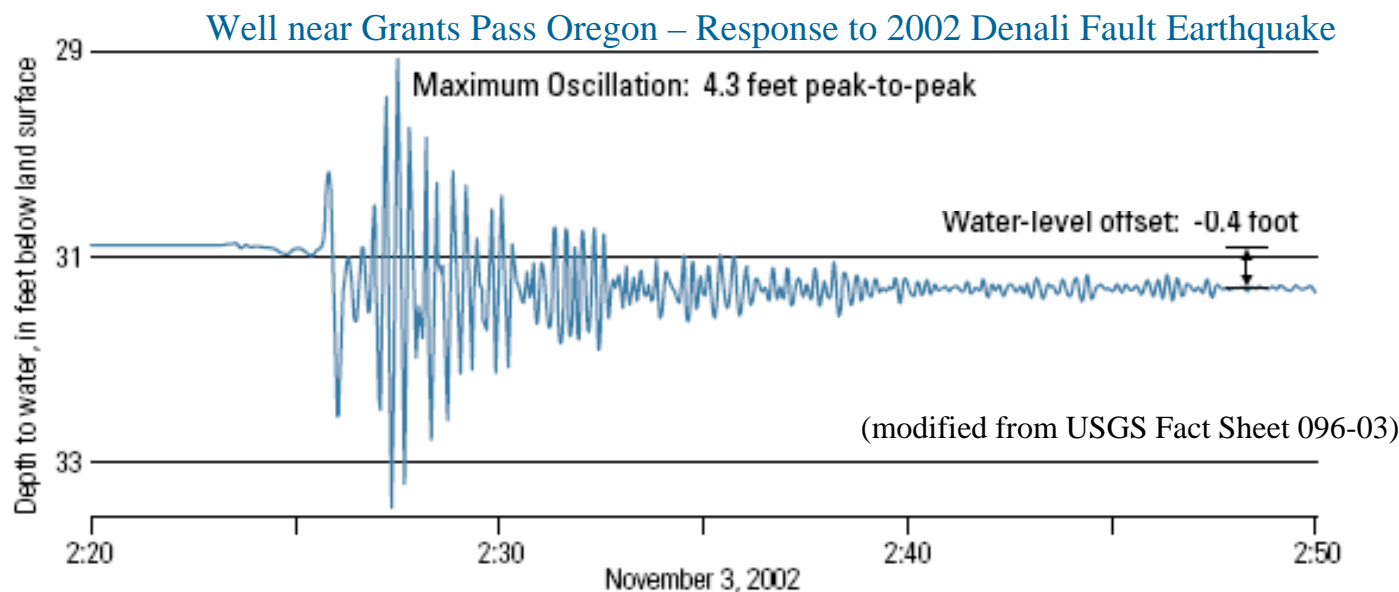
Earthquake epicenters

Earthquakes

- Common hydrogeologic responses
  - Water-level oscillations due to seismic waves (dynamic strain)
  - Instantaneous water-level offsets due to aquifer compression/expansion (volumetric strain)
- Factors influencing response
  - Size, depth, distance from epicenter

- Seismic Waves
  - Cause water-level oscillations resembling seismograms
 - Only detected when water levels are recorded at very small (e.g., 1 s) intervals

Well near Grants Pass Oregon – Response to 2002 Denali Fault Earthquake

Maximum Oscillation: 4.3 feet peak-to-peak

Water-level offset: -0.4 foot

(modified from USGS Fact Sheet 096-03)

- # **Crustal Strain**
    - Fault movement causes rock compression and expansion
    - Coseismic +/- offset or step change in water level
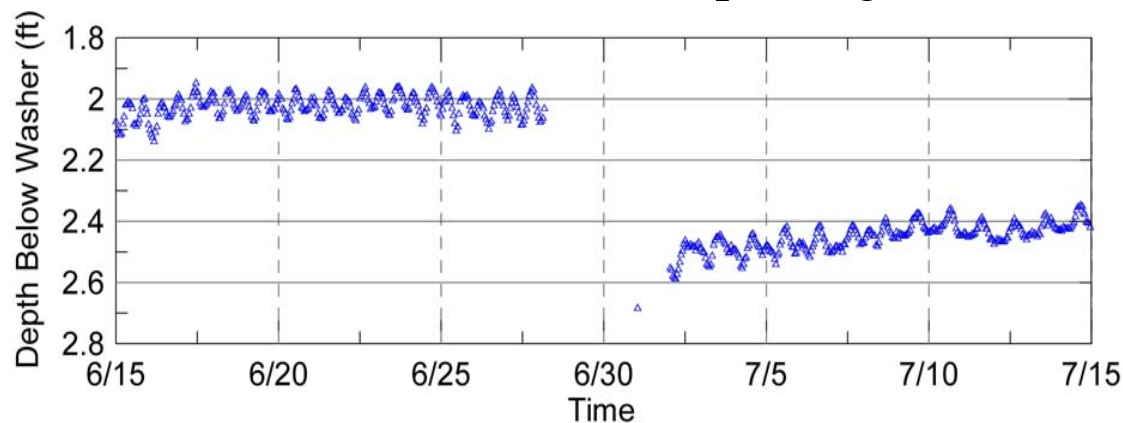
**1992
Landers/LSM:**

$\Delta WL > 0.7$ ft
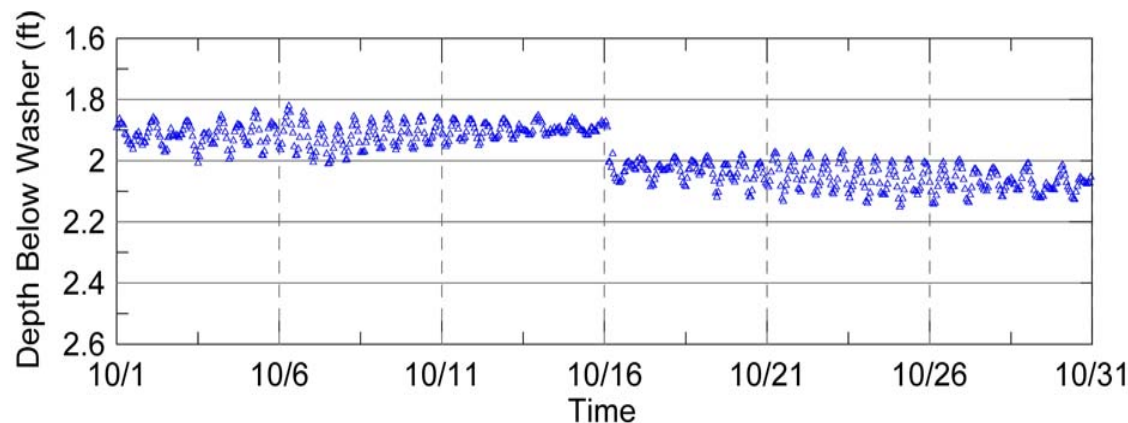
**1999
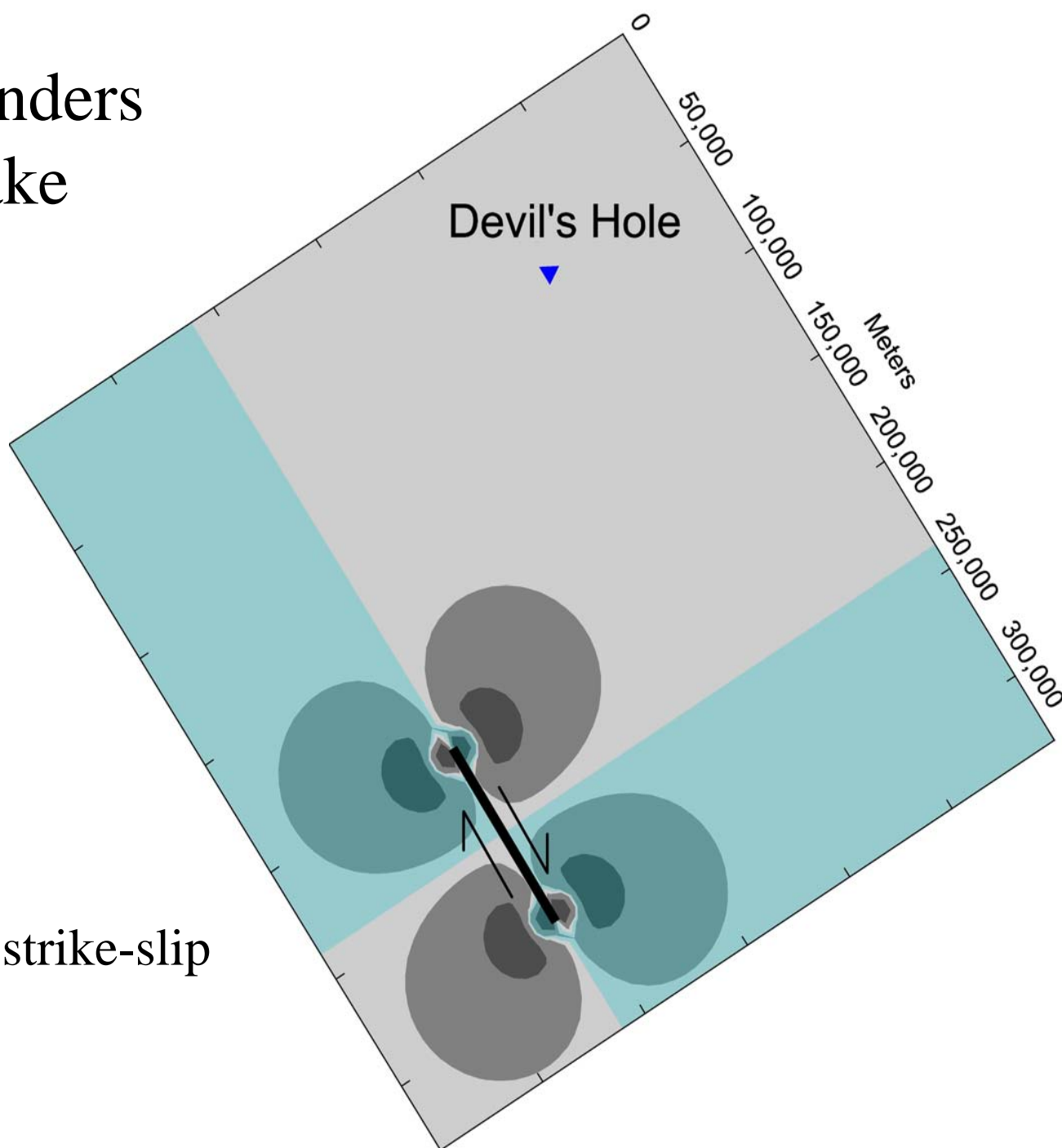Hector Mine:**

$\Delta WL = 0.1$ ft

Methods

- **Are the coseismic water-level offsets a result of the strain field produced by the earthquakes?**
  - Calculated volumetric strain field using known earthquake parameters and a dislocation model (Okada, 1992)
  - Converted change in strain to change in water level (Ge and Stover, 2000)
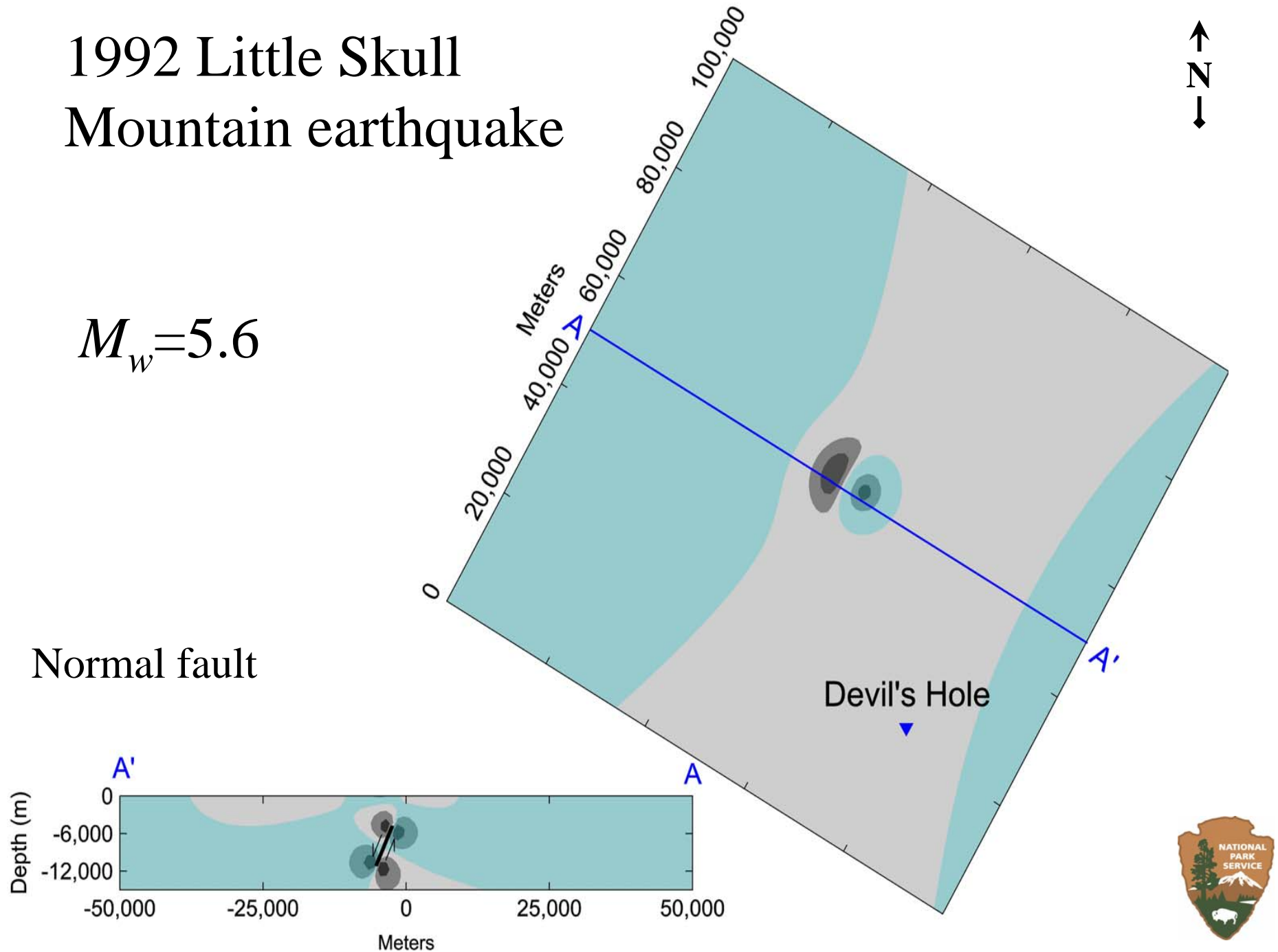
1992 Landers earthquake

M_w=7.3

Right-lateral strike-slip

Devil's Hole

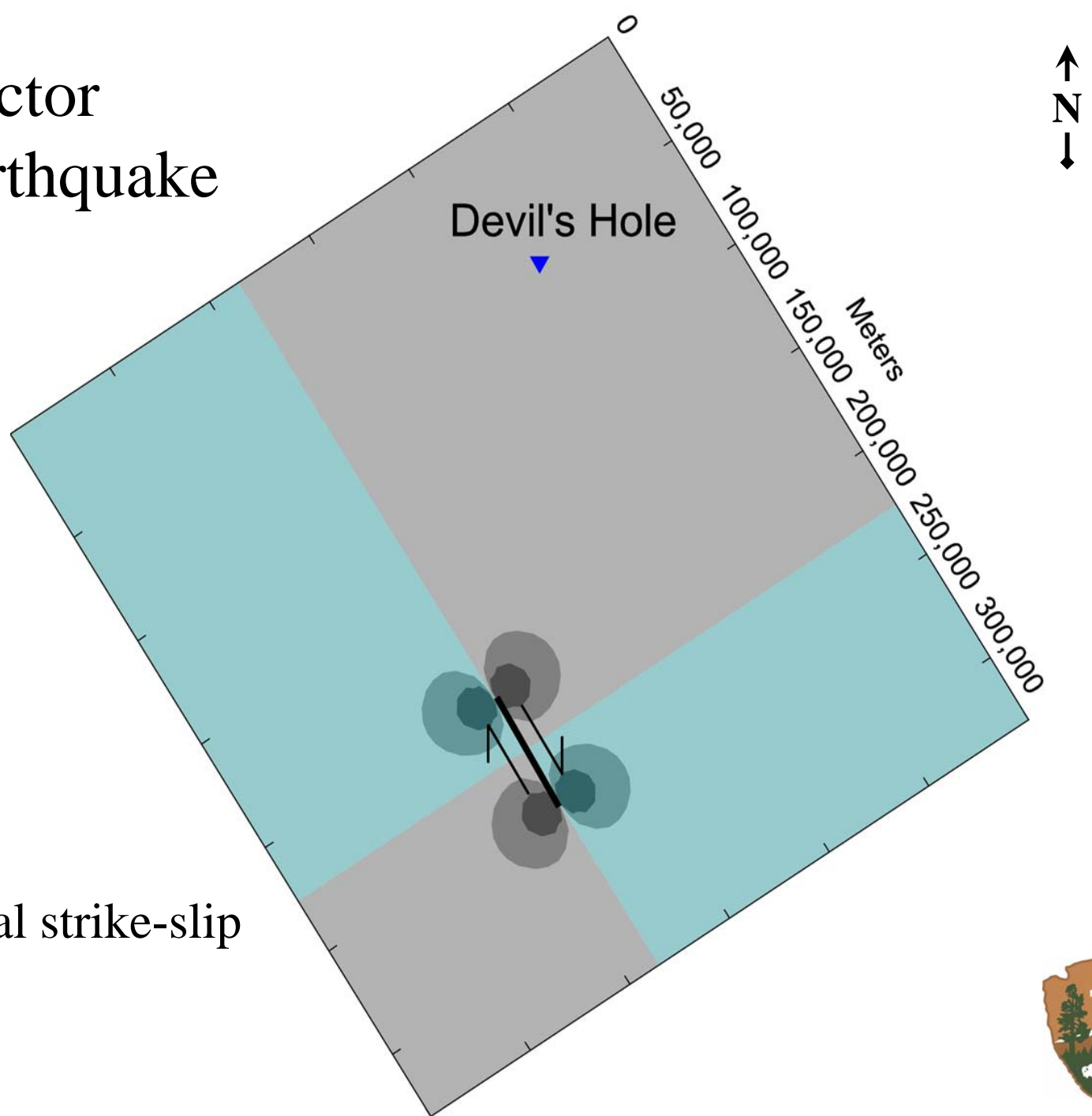# 1992 Little Skull Mountain earthquake

M_w=5.6

Normal fault

N

Meters
100,000
80,000
60,000
40,000
20,000
0

A
A'

Devil's Hole

A'
A

Depth (m)
0
-6,000
-12,000

-50,000   -25,000   0   25,000   50,000

Meters

1999 Hector Mine earthquake

$M_w = 7.0$

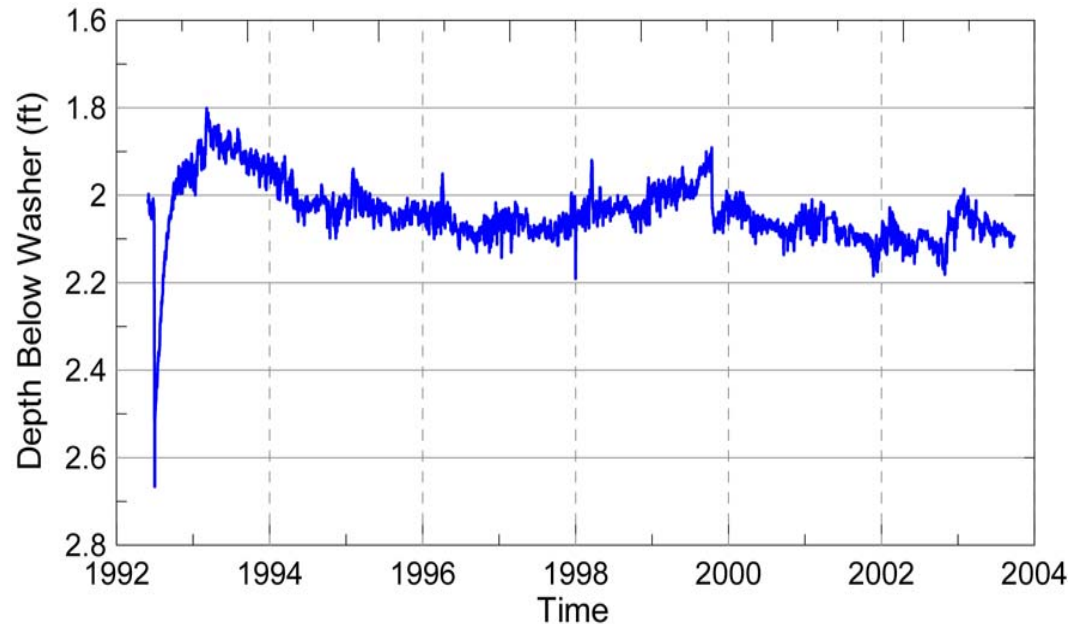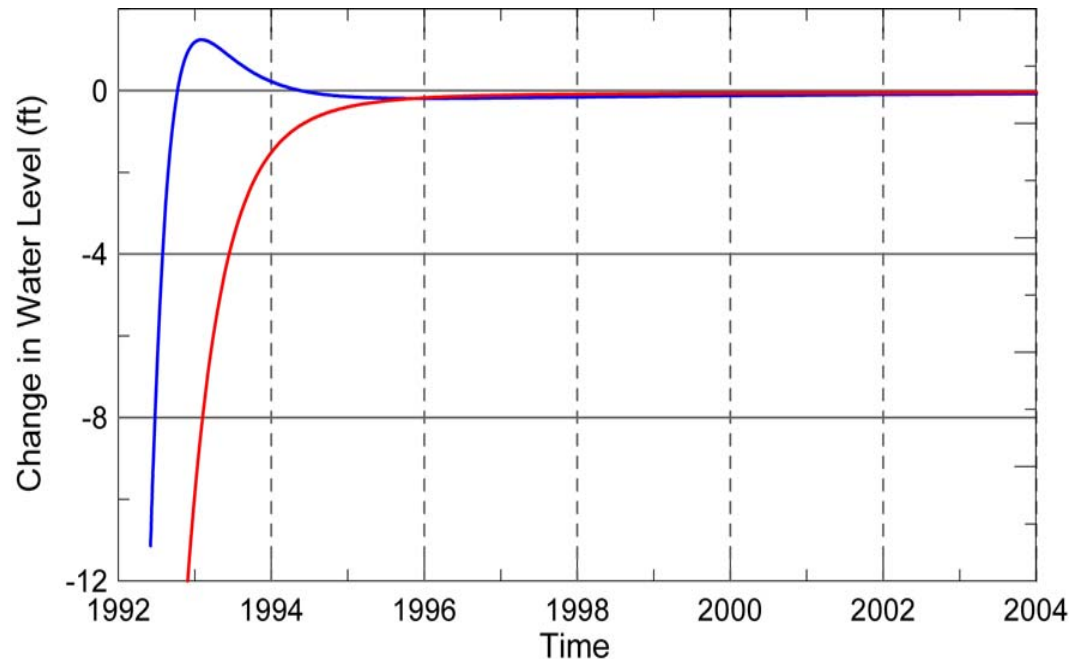Right-lateral strike-slip

Devil's Hole

Summary & Conclusions

- Coseismic water-level offsets agree with modeled volumetric strain in sign and magnitude

- Installation of strain meter(s)

- Future work - understand postseismic recovery

Postseismic Recovery - Little Skull Mtn. Earthquake

Filtered daily mean water level at Devil's Hole

Simulated water level near LSM fault zone

Conclusions

- Water-level fluctuations due to air pressure and earth tides are relatively small

- Coseismic offsets are likely a result of volumetric strain

- Installation of barometer and strain meter(s) will aid in filtering future water levels, and will aid in understanding postseismic water-level recovery

Acknowledgements

- NPS, Water Rights Branch
  - Chris Gable, Brad Gillies

- NPS, Death Valley National Park
  - Terry Fisk, Jim Roche